CHANNEL CALCULATIONS FOR WHITE SPACES GUIDELINES

Revision 1.29

3/6/2013

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Revision History

Draft Revision 0.1 – Initial Draft 3/28/2011

Draft Revision 0.2 – Incorporated changes in the week of 3/28/2011 – 4/04/2011

Draft Revision 0.3 – Incorporated comments received in the week of 04/04/2011 and comments made at the teleconference on 04/11/2011

Draft Revision 0.4 – Incorporated comments received on 04/12/2011

Draft Revision 0.6 – Including Telcordia's Comments of 4/13/11 and redacting questionable items

Draft Revision 0.7 – Consensus previous to meeting in Baltimore 4/19/11

Draft Revision 0.8 – Consensus from meeting in Baltimore to present to FCC OET 4/20/11

Draft Revision 0.9 – Added FCC OET DTS protection suggestions

Draft Revision 0.91 – Modified FCC OET DTS protection graphic, added template for other TV protection criteria. corrected several typos

Draft Revision 0.92– Added TV protection tables, Offshore Radio protection table and Canadian Diagram, changed Canadian Terrain Data source

Draft Revision 0.93 – Offshore Radio protection table corrected, added provisional URL's for Canadian and Mexican borders, deleted sections on Update times and Attachments

Draft Revision 0.94 – Changed focus to "Channel Calculation" from "Contour Protection", added several other protection specifications and Polygon Definition

Draft Revision 0.95 – Added protection descriptions for various TV receive antenna systems, polygon definition added.

Draft Revision 0.96 – Revised polygon definition, made several corrections.

Draft Revision 0.96b – Reformatted subsections in Sections 4 and 6; added reference to terrain database boundaries; clarified Section 6.2.3: Polygon Description for Wireless Microphone Protection.

Draft Revision 0.97 – Updated Sections 2.1 – cleaned up CDBS codes used and 6.4 – added the list of the protected sites

Draft Revision 0.98 – Updated Sections 5, 6.1 and 6.23 with explanations of underlying rules

Draft Revision 0.98b – reformatted the document, updated section §6.4 – added sites in Sugar Grove, WV, Boulder, CO and Socorro, NM

Release Candidate 1.0 – added figures to section 6.3.3 MVPD Headends, numerous editorial corrections

Draft Revision 1.10 – added sections 2.3.1 Terrain Database Interpolation, 3.8 F-Curve Interpolations, and 7 F-Curve Interpolation Data Points

Draft Revision 1.20 – added section 3.9 Antenna Pattern Minimum Value Clamping

Draft Revision 1.21 – Updated section 3.6 to specify zero elevations for null terrain points, and added HAAT lower and upper clamping values of 30 and 1600 meters respectively

Draft Revision 1.22 – Updated section 2.1 to add clarification to extracted fields from CDBS. Updated section 2.3 and added section 2.3.1 to define terrain extraction logic at the Canadian border and between overlapping tiles. Updated §6.2.3 to revise language for wireless microphone area protection

Draft Revision 1.23 – Updated protected contour separation distances and radio astronomy site coordinates to reflect the latest changes in the FCC's Third Memorandum Opinion and Order

Draft revision 1.24 -- Added processing guidelines for understanding and using Canadian TV records

Draft revision 1.25 -- Added §4.5: Contour Calculation methods for non-US contours intersecting the US border

Draft revision 1.26 -- Added Polygonal Intersection description to §4.5, made numerous editorial typographical corrections

Published revision 1.27 -- Added 12 NM territorial limit to §1, added Microsoft, corrected several remaining typos

Draft Revision 1.28 -- Added Note concerning agreed times for changing updated data in §1, corrected Mexican boundary file reference and added 50k DEM reference for Canadian Geobase data

Draft Revision 1.29 – Added description of process for choosing Canadian antenna patterns.

Table of Contents

1. Definition of Scope

This specification covers precise implementation of calculations of protection contours and distances to these contours as defined by FCC rules. These calculations are applicable only to locations within the territorial United States of America, as defined by the border files in §4.4 and §4.5 and within the 12 nautical mile limit beyond US soil, available at http://www.nauticalcharts.noaa.gov/csdl/mbound.htm.

The intent of this specification is to establish, ensure and validate consistency between WSDBA members. It is developed by the following database providers: Airity, Inc., Comsearch, a CommScope Company, Frequency Finder, Inc., Google Inc., LS telcom AG, Neustar, Inc., Spectrum Bridge, Inc., and Telcordia Technologies, Inc. and subscribed to by Microsoft.

This document is correct as of the date of release. All information contained within is subject to change. Note particularly that many of the data used and referenced here also change with time, and that the Members agree from time to time if and when changes to data are to be made.

2. Input Data Sources

The following shall be the default data sources used for all contour-related calculations:

2.1 FCC CDBS Database

The CDBS database shall be retrieved from:

http://www.fcc.gov/mb/databases/cdbs

The source file names shall be “tv_eng_data.dat”, “ant_pattern.dat”, "application.dat", "app_tracking.dat" and “facility.dat”.

For current ordering of data fields within the file, refer to:

http://www.fcc.gov/ftp/Bureaus/MB/Databases/cdbs/_readme.html

The data fields retrieved for each protected site shall include:

1. Service (vsd_service)
2. Channel
3. Directional Antenna (DA) or NonDirectional (ND)
4. Effective Radiated Power (kW)
5. N (North) or S (South) Latitude
6. Degrees Latitude
7. Minutes Latitude
8. Seconds Latitude
9. W (West) or (E) East Longitude
10. Degrees Longitude
11. Minutes Longitude
12. Seconds Longitude

13. Height of Antenna Radiation Center Above Mean Sea Level (RCAMSL)
14. Directional Antenna Pattern Rotation (degrees)
15. Antenna Radiation Center Height Above Ground Level (RCAGL)
16. Antenna Height Above Average Terrain (HAAT)
17. Antenna ID
18. From ant_pattern.dat, all fields corresponding to the Antenna ID

Records with a channel number outside the range of 2 thru 51 can be ignored since they do not impact whitespace channel selection.

The Directional Antenna indicator is only true if it is equal to "C" or "D". If the field is empty or contains any other letter, the site shall be treated as a Non-Directional (omni) transmitter.

If a Directional Antenna indicator is set, but the Antenna ID is missing from the antenna pattern database, the site shall be treated as a Non-Directional (omni) transmitter.

If the Antenna Pattern Rotation field is missing, it shall be treated as a rotation value of 0 degrees.

Coordinate data in the CDBS is projected using the NAD27 datum.

Antenna RCAMSL height shall be used for elevation calculations. If the RCAMSL field is missing, then the RCAGL height plus terrain elevation shall be used instead. If both RCAMSL and RCAGL fields are missing, then the HAAT value minus the "Station HAAT" (see section 3.7) plus terrain elevation shall be used instead.

Records that are missing all three antenna height parameters (RCAMSL, RCAGL, and HAAT) shall be ignored.

Data identified with following database keys shall be ignored:

Database keys: vsd_service = LM|Land Mobile| or

NM|NTSC Channel Change| or

NN|New NTSC Allotment| or

TR|Proposed Rulemaking to Amend the Table of Assignments| or

DM|DTV Channel Change| or

DN|DTV New Allotment| or

DR|DTV Channel Substitution| or

DS |Digital TV STA | or

TS|Analog Special Temporary Authority| or

TA|TV Allotment|

The data retrieved shall be identified as belonging to one of the following categories, as classified by the vsd_service database key:

2.1.1 Digital TV Stations

Database keys: vsd_service = DT|Digital TV|

2.1.2 Digital and Analog Class A TV Stations

Database key: vsd_service = CA | Class A TV Station| or

DC | Digital Class ATV Station |

2.1.3 Low Power, TV Translator and Booster Stations

Database key: vsd_service = TX | TV Translator or LPTV Station| or

LD | Digital TV Translator or LPTV Station | or

DD| DTV Distributed Transmission System (DTS) |

2.1.4 Canadian and Mexican Border Stations

Database key: vsd_service = TV | Television

2.2 FCC ULS Database

The ULS database shall be retrieved from:

http://wireless.fcc.gov/uls/index.htm?job=transaction&page=weekly

Coordinate data in the ULS is projected using the NAD83/WGS84 datum.

The following files shall be retrieved from the website:

- l_LMbcast.zip
- l_LMcomm.zip
- l_LMpriv.zip
- l_micro.zip
- l_paging.zip

These files contain all necessary data for protected areas.

The following shall be the sources for information for respective protected stations:

2.2.1 Broadcast Auxiliary Service Stations (Including Receive Only Sites), Except Low Power Auxiliary Stations

- File: l_LMbcast.zip
- File: l_micro.zip

2.2.2 PLMRS Base Stations Located More than 80 Km from the Geographic Centers of the Metropolitan Areas and on the Channels 14 Through 20

- Files: l_LMpriv.zip

2.2.3 CMRS Base Stations Located More than 80 Km from the Geographic Centers of the Metropolitan Areas and on the Channels 14 Through 20

- Files: l_LMcomm.zip

2.2.4 Other Protected Entities

- File: (to be described)

2.3 Terrain Database

A new, NAD83/WGS84 projected terrain database shall be generated using the publicly available National Elevation Database available at seamless.usgs.gov and Canadian data from http://www.geobase.ca (using 50k DEM data).

Database shall include area necessary to provide for contour calculation of any Canadian or Mexican stations near the border.

The Canadian database shall be used within the boundaries of Canada, as defined by the border file in Section 4.3.

The NED database shall be used everywhere else.

2.3.1 Resolving Terrain Overlap

Terrain data files are generally organized in "tiles" (rectangular rasters aligned to latitude and longitude bins) that include overlapping data along each of its edges. When overlapping tiles contain non-identical data in their overlapping zones[1], there is the potential for elevation ambiguity in those areas.

To resolve this ambiguity, the following tile selection methodology shall be used. For any given point, exactly one terrain tile will be selected as the authoritative source of elevation data.

[1]USGS terrain data has been shown to have non-identical data in overlapping tile regions. This may turn out to be a common occurrence for all terrain databases because tiles are generally updated independently of one another (derived from different data sources and processed by different groups of people). There is no guarantee that the overlapping data must be identical.

1. For any given point (`lat` and `lon`), determine if it is inside of Canada or not (using boundary definition in section4.3 below). Points inside Canada shall use GeoBase terrain tiles, while all others shall use USGS terrain tiles.
2. Determine the set of tiles that include the requested `lat` and `lon` coordinates[2]. The number of matching tile candidates is expected to be between 0 and 4.
    a. If the number of matching tiles is 0 (point does not fall within any terrain tile), then treat the elevation as 0 meters and return.
    b. If the number of matching tiles is 1, then the point does not have any data overlap issues. Proceed to the terrain interpolation algorithm of section 2.3.2 using the selected tile.
3. If 2 or more tile candidates are found, use the following criteria to select which tile to use.
    a. Compute the latitude distance from `lat` to each candidate tile[3]. The tile(s) with the smallest latitudinal distance (`lat_distance`) wins.
    b. In case of a tie, compute the longitude distance from `lon` to each candidate tile[4]. The tile(s) with the smallest longitude distance (`lon_distance`) wins.
    c. In case of a tie, select the tile with the lowest latitude and lowest longitude coverage (i.e., lowest numerical values).
    d. Proceed to the terrain interpolation algorithm of section 2.3.2 using the selected tile.

    Hint: This is effectively the same as sorting the candidate tiles according to multiple keys. The primary key is the $\texttt{lat\_distance}_i$, followed by $\texttt{lon\_distance}_i$, $\texttt{center\_lat}_i$, and $\texttt{center\_lon}_i$ to resolve any ties when necessary.

Illustrated Example

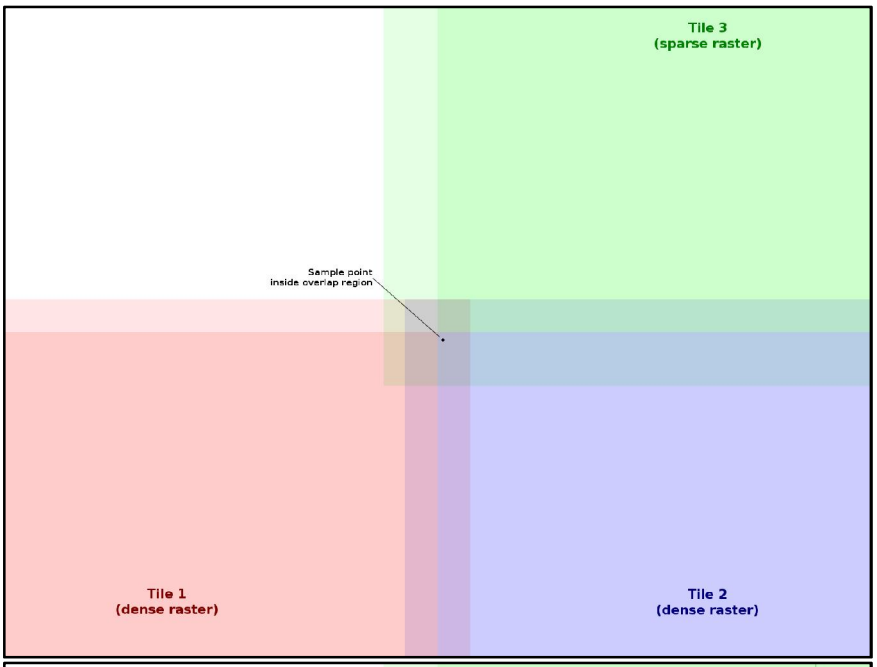
[2]The recommended method for determining tile coverage is to read the metadata associated with each tile, however, in many cases it is also possible to determine the extents of a tile from the file name alone (using appropriate parsing and decoding logic). The metadata approach is preferred because it is more robust against changes to naming conventions, raster density changes, and future changes to the terrain tile organization.

[3] The "latitude distance to a tile" is the difference between `lat` and the center latitude of a tile (i.e., $center\_lat_i = \frac{min\_lat_i + max\_lat_i}{2}$). In other words, $lat\_distance_i = abs(lat - center\_lat_i)$.

[4] The "longitude distance to a tile" is the difference between `lon` and the center longitude of a tile (i.e., $center\_lon_i = \frac{min\_lon_i + max\_lon_i}{2}$). In other words, $lon\_distance_i = abs(lon - center\_lon_i)$.

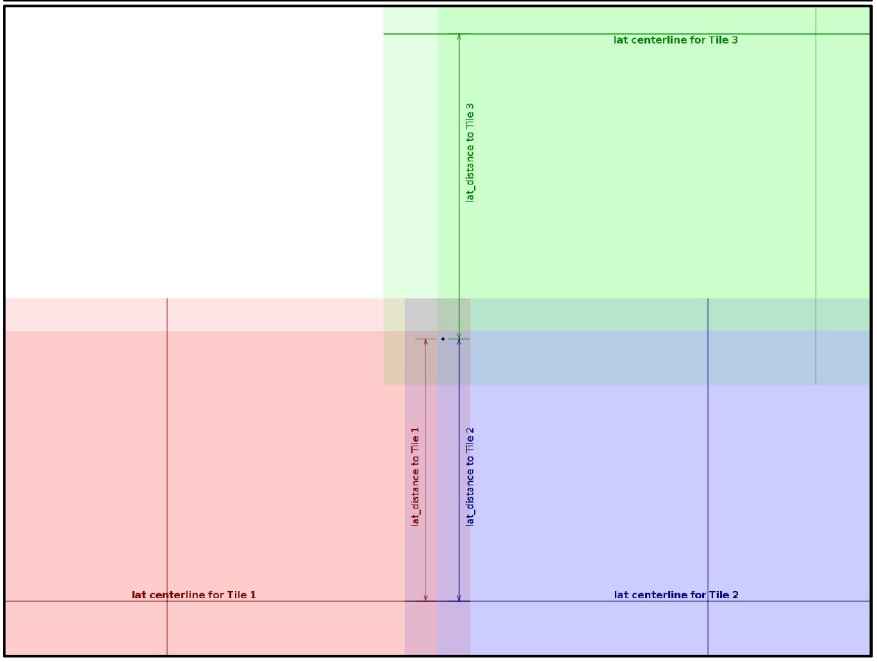
Consider a sample point that lies in the overlap zone between three tiles.

Note that the tiles do not necessarily have the same raster density or coverage range.



Since there are 2 or more candidate tiles to consider, they need to be ranked according to $\texttt{lat\_distance}_i$.

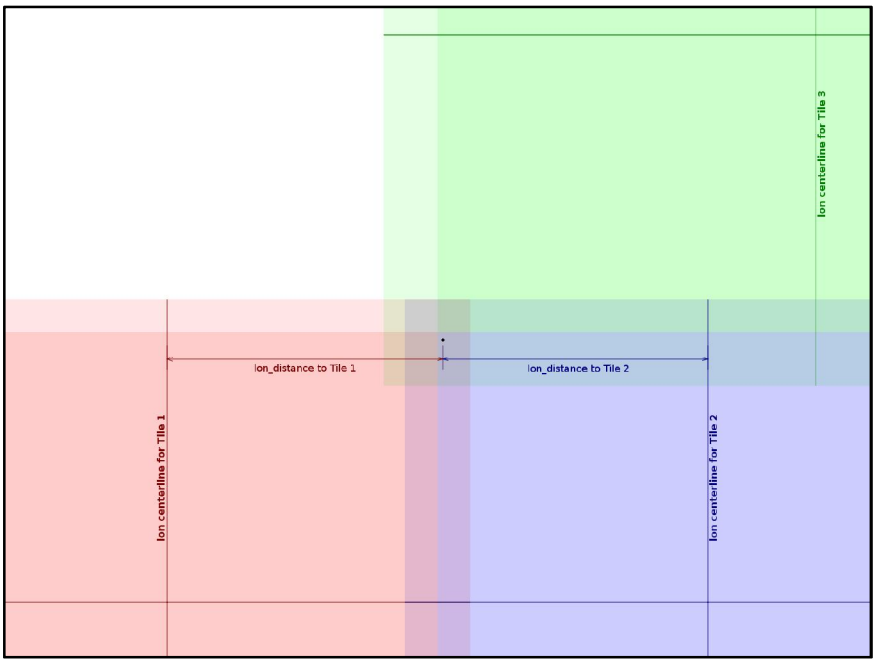
In this example, Tile 1 and Tile 2 have the same `lat_distance`. Both tiles are closer to the sample point than Tile 3.



Since the `lat_distance` for Tile 1 and Tile 2 is the same, the `lon_distance` needs to be checked.

In this example, Tile 2 is closer than Tile 1.

Tile 2 is selected as the authoritative tile to use with the terrain interpolation algorithm in section 2.3.2.



2.3.2 Terrain Database Interpolation

All used terrain databases shall use linear interpolation of the grid sample points to calculate the actual AMSL of a sample point according to the following pseudo-code:

```
y1 = abs(lat - pt_corner_lat(1))*PTS_PER_DEG_LAT;
x1 = abs(lon - pt_corner_lon(1))*PTS_PER_DEG_LON;
y2 = 1 - y1;
x2 = 1 - x1;
elevation = corner_el(1) * x2 * y2;
elevation = elevation + corner_el(2) * x2 * y1;
elevation = elevation + corner_el(3) * x1 * y1;
elevation = elevation + corner_el(4) * x1 * y2;
```

where:

`lat` is latitude of the sample point whose elevation needs to be retrieved
`lon` is longitude of the sample point whose elevation needs to be retrieved
`PTS_PER_DEG_LAT` is the number of points per degree latitude of the terrain data file containing the sample point
`PTS_PER_DEG_LON` is the number of points per degree longitude of the terrain data file containing the sample point
`pt_corner_lon(x)`, where `x = {1, 2, 3, 4}`, is the longitude of the target tile corner `x`
`pt_corner_lat(x)`, where `x = {1, 2, 3, 4}`, is the latitude of the target tile corner `x`
`corner_el(x)`, where `x = {1, 2, 3, 4}`, is the elevation of the target tile corner `x`
`elevation` is the output of the calculation
Target tile is the tile whose four corners are the four corners closest to the sample point.

Corners shall be numbered consecutively in either clockwise or counter-clockwise direction. Corner 1 may be the South East corner and the corner orientation may be counter-clockwise, as in the original FCC-supplied code that can be retrieved from: ftp://ftp.fcc.gov/pub/Bureaus/Engineering_Technology/Software/tv_process.zip

Where extracted points are very close to the US-Canadian border, the border file shall determine which database is used. If no points exist within the determined database exist at one or more of the four corners above, the elevation value for that point shall be equal to the average of the available corners, or zero if no points are available.

3. Used Algorithms

The following algorithms shall be used in all pertinent calculations.

3.1 Formula for Distance Calculations

The distance between any two points shall be calculated according to the Vincenty method. The method and equations can be found at:

http://www.ngs.noaa.gov/PC_PROD/Inv_Fwd/

3.2 NAD27 to NAD83 Coordinate Translation

All geographic coordinates sent by the database shall be projected in the NAD83 or WGS84 format.

For CDBS TV station location data received in NAD27 format, the NADCON translation algorithm to NAD83 shall be used.

3.3 Power Determination

No mechanical or electrical beam tilt shall be included in the contour calculations or Effective Radiated Power ("ERP") determination. ERP shall be obtained by linearly interpolating the field values between directional pattern azimuths in CDBS.

3.4 Contour Calculation

Contours shall be defined as 360 straight lines connecting 360 calculated contour vertices. Vertices shall be calculated at one degree increments around the station location, using the Radial HAAT method in Section 3.6 for each radial.

The FCC-supplied algorithm as derived from FCC "F" Fortran code, with FCC extracted tables representing the propagation charts from §73.699 shall be used to calculate the R-6602 contour vertex locations. These must be accurate to within ten meters.

3.5 Distances to Contours

A distance between any point and given contour is determined as the shortest distance to any contour line or vertex.

To illustrate, see Figure1: Contour Distance Calculation~~Figure1: Contour Distance Calculation~~. Contour C is approximated by the contour points C1 through C360. Two points P1 and P2 are external to the contour C. The distance of P1 to the contour is defined as the perpendicular distance from P1 to the line segment C4-C5, as no other line or vertex is closer. The distance of P2 to the contour is defined as the distance of P2 to the contour vertex C6, as it is shorter than the distance of P2 to any point on either of the two line segments C5-C6 and C6-C7.

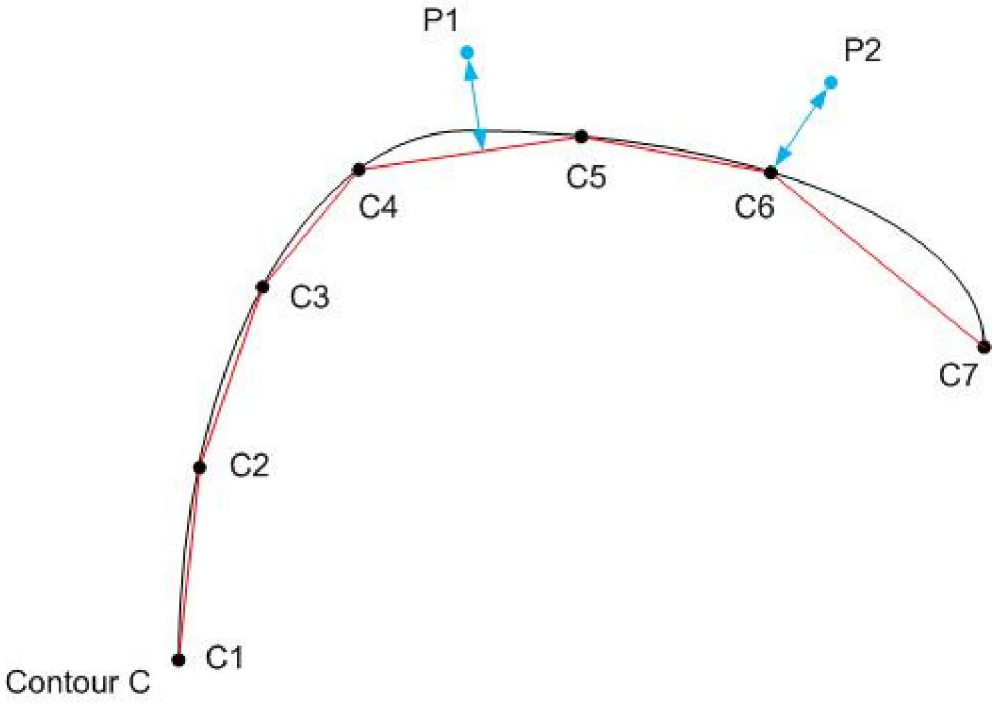


Figure1: Contour Distance Calculation

3.6 Radial HAAT Calculations

To calculate a radial Height Above Average Terrain ("HAAT") for a given azimuth from a pair of coordinates, a set of 130 elevations of points at 100 meter intervals beginning at 3.2 kilometers and ending at 16.1 kilometers from the station shall be extracted and averaged. The two endpoints shall be determined using the method of section 3.1, and the intervening coordinate pairs obtained by linear interpolation. The elevation at each point shall be linearly interpolated from the four adjacent tiles. In addition, each radial HAAT shall be calculated from elevations along the radial regardless of borders and bodies of water. In cases of islands or continental coasts where no data is returned by the terrain databases, zero elevation shall be presumed. HAAT values of 30 meters or less shall be given as thirty, and those of 1600 meters or more as 1600.

3.7 Station HAAT Calculations

Station HAAT is an average of 8 radial HAAT values taken in 45° steps: 0° True, 45°, 90°, 135°, 180°, 225°, 270°, and 315°.To calculate station HAAT the entire radial lengths from 3.2 to 16.1 kilometers, of all eight radials, regardless of borders and water, shall be used.

3.8 F-Curve Interpolation

The F-Curves shall be interpolated according to the FCC's Fortran code located at http://www.fcc.gov/mb/audio/bickel/archive/fmtvcurves.zip

3.8.1 Free Space Calculations

The output of the free space distance calculations shall be limited to a maximum of 1.5 km.

3.8.2 F-Curve Interpolation Points

The F-curves shall be interpolated using the data points defined in the tvfmfs_metric() subroutine of the FCC's Fortran code. These values are listed in the tables in Section 7 below.

3.9 Antenna Pattern Minimum Value Clamping

For all record entries in all antenna pattern files, if a directional value at any azimuth falls below 0.001 relative field (one thousandth), it shall be set to 0.001 for all contour calculations.

4. TV Protection Criteria

4.1 TV, Class A TV, LPTV, Translator Outputs

Protected TV contour values are:

Table 1

(units in dBµV/m)	Low (2 - 6)	High VHF (7 - 13)	UHF (14 - 52)
Analog F(50,50)	47	56	64
Digital F(50,90)	28	36	41

Fixed device separation distance (in km) from protected contours are:

Table 2

Antenna height above average terrain ("HAAT")	Co-channel (km)	Adjacent Channel (km)
HAAT < 3 meters	4.0	0.4
3 <= HAAT < 10 meters	7.3	0.7
10 <= HAAT < 30 meters	11.1	1.2
30 <= HAAT < 50 meters	14.3	1.8
50 <= HAAT < 75 meters	18.0	2.0
75 <= HAAT < 100 meters	21.1	2.1
100 <= HAAT < 150 meters	25.3	2.2
150 <= HAAT < 200 meters	28.5	2.3
200 <= HAAT <= 250 meters	31.2	2.4

Note that personal / portable devices will always use the first row of this table (“HAAT< 3 meters” values) to calculate contour separation distances.

4.1.1 Translator Inputs

See section 5, "Other protected Entities"

4.2 DTS

The population served by Distributed Television Service stations shall be the population within the station’s combined coverage contour, excluding the population in areas that are outside both the DTV station’s authorized service area and the Table of Distances area, as follows:

Table 3

Channel	Zone	F(50,90) Field Strength	Distance from Reference Point (km)
2 - 6	1	28	108
2 - 6	2 and 3	28	128
7 - 13	1	36	101
7 - 13	2 and 3	36	123
14 - 61	1, 2 and 3	41	103

For DTS records the reference point coordinates are in the CDBS tv_eng_data table; they are in the first row designated as site_number = 0, and must be converted from NAD 27.

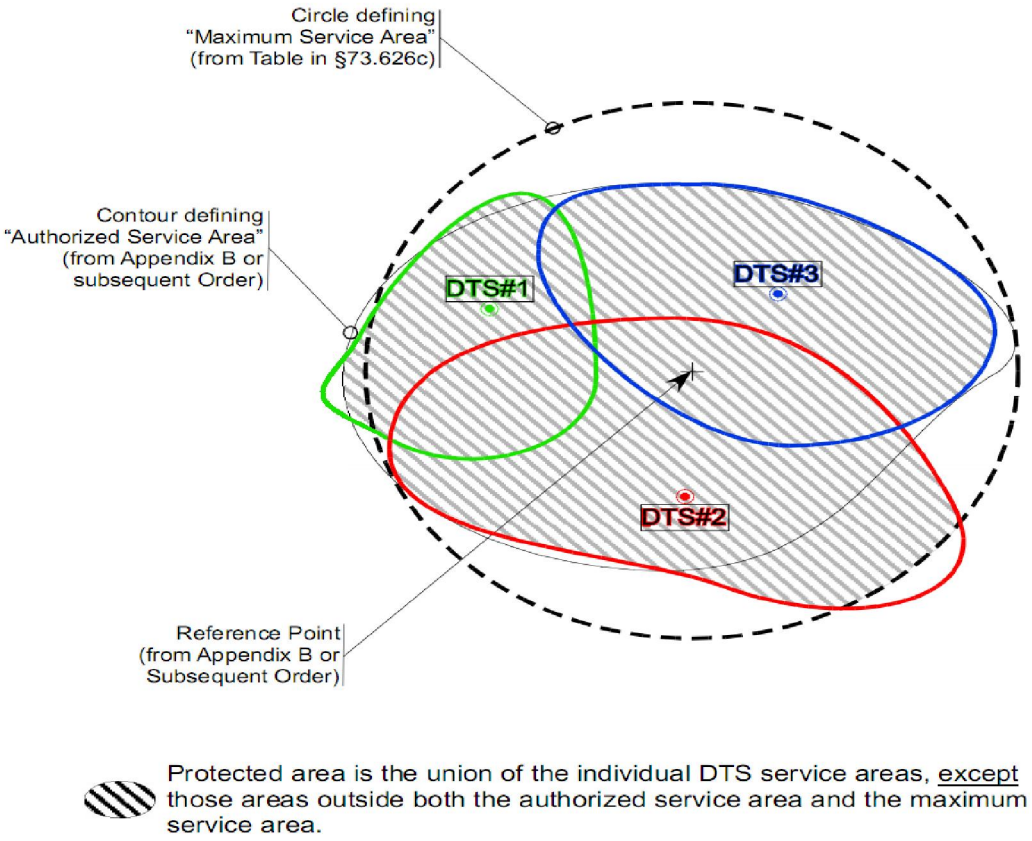


Figure 2: Distributed Television Service Protection

4.3 Canadian TV Protection

Those records which have the "tvstatio.banner" code equal to either AU (Authorized), OP (Operational) or TO (Temporary Operation) and the "tvstatio.border" code less than 400 km are extracted from the Canadian DBF III file set and placed on the FCC's website. TV white space database systems shall use Canadian TV station engineering data from Industry Canada's licensing system since what is internationally proposed and listed in the CDBS may not reflect actual as-built stations. Industry Canada's TV station engineering data for actual operations is placed on the FCC's website daily using the following procedure and may be obtained by the database systems from the FCC's website.

Industry Canada's broadcast station assignment database ("baserad.zip") consists of one "*.txt file", 28 "*.DBF III files", and one "*.DBT file", which provide all the licensing and operational information on each AM, FM and TV station and allotment in Canada. Only the following five files are needed to fully protect Canadian Television operations from TVBDs: "APATDAT.DBF", "APATDESC.DBF", "APATKEY.DBF", "APATSTAT.DBF", and "TVSTATIO.DBF". The five Industry Canada files are converted into ASCII, pipe-delimited records and zipped into the file <http://data.fcc.gov/download/white-space-database-administration/ca_tv_data.zip>. Latitudes are currently expressed in degrees, positive for Northern

Hemisphere and negative for Southern Hemisphere. Unless otherwise indicated latitudes are expressed in + DDMMSS. Longitudes are currently expressed in positive degrees only and have the meaning of West. Some longitudes exceed 180 degrees. Unless otherwise noted longitudes are expressed in + DDDMMSS. Latitude & Longitude are in the NAD83 datum. Unless otherwise noted, antenna heights are in meters(m) and distances are expressed in kilometers (km).

To determine whether a station is analog or digital for contour calculations, the TV modulation information in the tv_statio.txt file is used. The TV modulation information is contained in column ERPATA and is coded as 0=Analog; 1=Digital and 2=Post-transition (i.e., Digital). So if the ERPATA value is 1 or 2, the station is a digital station, otherwise it is an analog station.

Visual Peak power (ERP) is used for both analog and digital station contour determination. For the few records with "0" Visual Peak power and a non-zero entry for Visual Average power , assume that the supplied average power value is also the peak power. In cases where both the Visual Peak and Visual average power are zero, assume the Visual Peak power is 1 kW. Ignore tilt angle.

For records with no useful height information (i.e., no entry for HAAT, RC, or AGL, use the DEM height as the true ground elevation and assume AGL of 30 meters.

Stations in this database above channel 51 and all US stations (with a state rather than a province abbreviation) shall be ignored.

The file tv_apatdat.txt contains antenna pattern information for antennas associated with each of the television station transmitters. Each television record present in the tv_statio.txt file has an associated unique key called "CALLS_BANR_KEY" in the file. This key is used to cross-reference antenna pattern information in other files. For each station, the CALLS_BANR_KEY is used to find an antenna pattern key called "PATT_KEY" in the tv_apatstat.txt file, which is then used to find antenna pattern information in the file tv_apatdat.txt. It is possible to have several antenna patterns, each with a distinct PATT_KEY value associated with the same station, identified by its CALLS_BANR_KEY. Antenna patterns may be present for both V and H polarization, as well as with different resolutions, i.e., number of pattern values per degree. Each of the different patterns will have a unique PATT_KEY value and the type of pattern is identified in the tv_apatdesc.txt file with the HOR_VER and PATT_TYPE fields. The possible values of HOR_VER are V and H, and the possible values for the PATT_TYPE field are PRECISE, BRIEF, and THEORETICAL. The following procedure will be used to choose the correct pattern for a station:

- Use the H-PRECISE pattern if present.
- If an H-PRECISE pattern is not present, use the H-BRIEF pattern.
- If an H-BRIEF pattern is not present, use the H-THEORETICAL pattern.
- If there are no H patterns, assume an omnidirectional pattern.

Canadian TV service shall be protected to the contour values of §4.1 at the US-Canadian Border identically to US TV facilities, except that the area within the Canadian contour but inside the USA is unprotected, which is illustrated in the figure below.

The file describing the US-Canadian border is available at the following URL:

http://transition.fcc.gov/oet/info/maps/uscabdry/uscabdry.zip

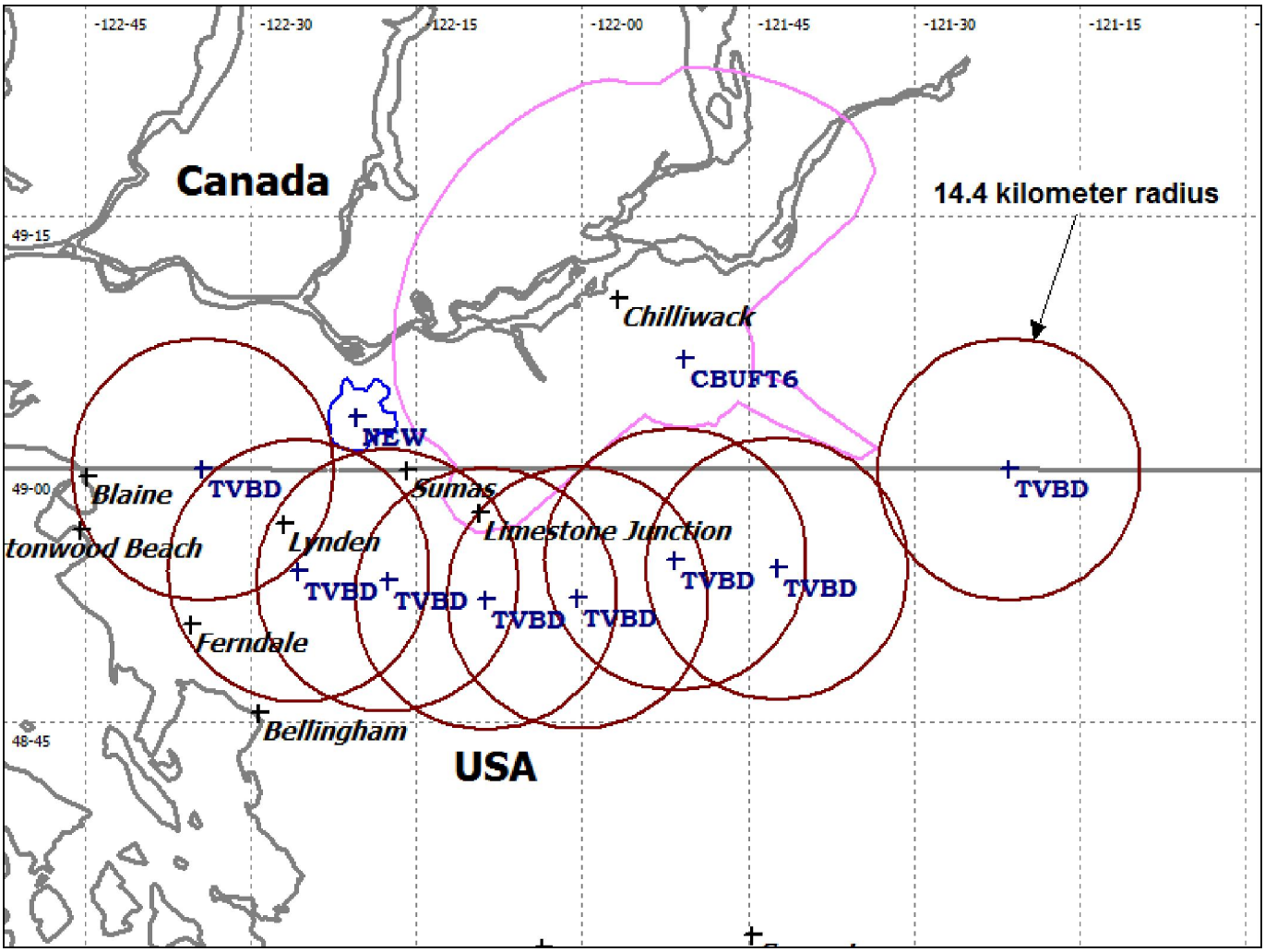


Figure 3: Canadian Border Protection

This example shows allowed fixed TVBD locations near the Canadian border protecting two Canadian TV facilities. This assumes like protection requirements as to US facilities, and omits many other records for clarity.

4.4 Mexican TV

Mexican TV service shall be protected to the contour values of §4.1 at the US-Mexican Border using values identical to US TV facilities, except that the area within the Mexican contour but inside the USA is unprotected.

The file describing the US-Mexican border is available at the **following URL:**

http://www.ibwc.gov/GIS_Maps/downloads/us_mex_boundary.zip

4.5 Non-US TV Contour Calculation

Protected Non-US TV contours shall be truncated at the US Border by polygonal intersection as follows: each pair of adjacent contour vertices which intersects the US border shall define a point at the border crossing. If the contour is approaching from foreign soil, continue along the border from the intersection point until the next intersection point is reached, and from thence along the usual contour vertices.

5. CMRS/PLMRS UHF "T-Band" Protection

The eleven metropolitan areas in which T-Band services exist are follows:

City	Latitude	Longitude	Channels
Boston, MA	42-21-24.4 N	71-03-23-2 W	14, 16
Chicago, IL	41-52-28.1 N	87-38-22.2 W	14, 15
Dallas/Fort Worth, TX	32-47-09.5 N	96-47-38.0 W	16
Houston, TX	29-45-26.8 N	95-21-37.8 W	17
Los Angeles, CA	34-03-15.0 N	118-14-31.3 W	14, 16, 20
Miami, FL	25-46-38.4 N	80-11-31.2 W	14
New York, NY	40-45-06.4 N	73-59-37.5 W	14, 15, 16
Philadelphia, PA	39-56-58.4 N	75-09-19.6 W	19, 20
Pittsburgh, PA	40-26-19.2 N	79-59-59.2 W	14, 18
San Francisco, CA	37-46-38.7 N	122-24-43.9 W	16, 17
Washington, DC	38-53-51.4 N	77-00-31.9 W	17, 18

These locations are to be protected by 134 kilometers for co-channel operation and 131 kilometers for adjacent channel operation. Protection of PLMRS/CMRS UHF T-Band base stations outside the 80 kilometer prescribed radii/channel combinations in the table, granted by waiver, are to be protected by 54 kilometers for co-channel operation and 51 kilometers for adjacent channel operation. The remaining two areas in the Rules (for Cleveland and Detroit) were never implemented due to Canadian concerns.

6. Other Protection

6.1 Offshore Radio Service

The Offshore Radio Service will be protected by prohibiting TVWS devices within the following areas:

	NW corner	NE corner	SE corner	SW corner
TV channel 15	N 30.5, W 96	N 30.5, W 92	N 28, W 92	N 28, W 98.5
TV channel 16	N 31, W 95	N31, W 86° 40'	N 29.5, W 86° 40'	N 29.5, W 96.5
TV channel 17	N 31.5, W 94	N 31, W 86.5	N 29.5, W 86.5	N 29.5, W 96
TV channel 18	N 31, W 95	N 31, W 87	N 29.5, W 87	N 29.5, W 95

The quadrilateral vertices are from §74.709(e), with the southern boundary of adjacent channel 18 protection defined by FCC as coincident with the southern boundary of channel 17.

Lines between points will be drawn on great circles.

6.2 Wireless Microphones

Wireless microphones operating in the TV spectrum may register their intended use so as to be protected, during the times and on the day of such registered use, from TVDB's according to §15.712(f).

6.2.1 Licensed Wireless Microphones

Licensed wireless microphone registrants, as for example Broadcasters, may register directly with the WSDBA of their choice. Registrations will be promptly shared with all other WSDBA's. Due to the infrequent (daily) requirement for TVDB's to reaffirm a channel list, protection will be guaranteed only when entered at least 48 hours prior to known event times. Emergent wireless microphone use must take place on one of the channels reserved for that use or risk interference.

6.2.2 Unlicensed Wireless Microphones

Unlicensed wireless microphone registrants, as for example churches or entertainment venues, must register with FCC, which will then share registration information with WSDBA's. The additional time required for dissemination from ULS is unknown at present, but will be at least 24 hours.

6.2.3 Area Description for Wireless Microphone Protection

15.712(f) allows only for a single protected point. In order to protect areas in addition to points, polygons for protection of Wireless Microphone registrants may be entered in one of two forms:

1. *A point, specified by geographic coordinates in NAD 83;or*
2. *A quadrilateral, represented by four latitude/longitude pairs, limited in size to three kilometers between any pair of vertices.*

In each case, a protected buffer of one kilometer (fixed TVBD's) and 400 meter (personal/portable TVBD's) will be created around the protected area by each recipient database.

Entities requiring larger areas may assemble them from either type, but not both in any single registration. Up to either twenty-five points or four quadrilaterals are allowed in a single registration.

6.3 TV receiving Antenna Protection

Area protected for TV receive antenna channels shall be a "keyhole" sized depending on co-channel or adjacent channel protection. If co-channel, the circle extends eight kilometers and the "keyhole" at most eighty kilometers, at plus and minus thirty degrees of arc from the azimuth toward the radiating TV station. If adjacent, the radius shall be two kilometers and keyhole at most twenty.

6.3.1 TV Translator Inputs

Sites receiving TV translator, LPTV and Class A signals which are within the protected contour of the station being received are not eligible for registration in the databases, as the contour will already be protected.

6.3.2 Broadcast Auxiliary Services

Permanent BAS sites from ULS and temporary BAS site registrations will be protected by keyhole as above save that the protection extends only as far as the transmitting station. These include TV Pickup, TV STL, TV Relay, TV Translator Relay and TV Microwave Booster stations.

6.3.3 MVPD Headends

Headend receive locations will be protected for each TV receive antenna using the keyhole above, which however is limited to either its maximum value above or to the distance to nearest point of intersection with the TV station's protected contour, whichever is less. Figures 4 and 5 illustrate co-channel protection, with an assumed 14.4 kilometer protection radius around the TVBD to the TV station, and adjacent channel protection, where the CATV Headend protection is limited to 20 kilometers and the WSBD must remain 740 meters from the protected TV contour.

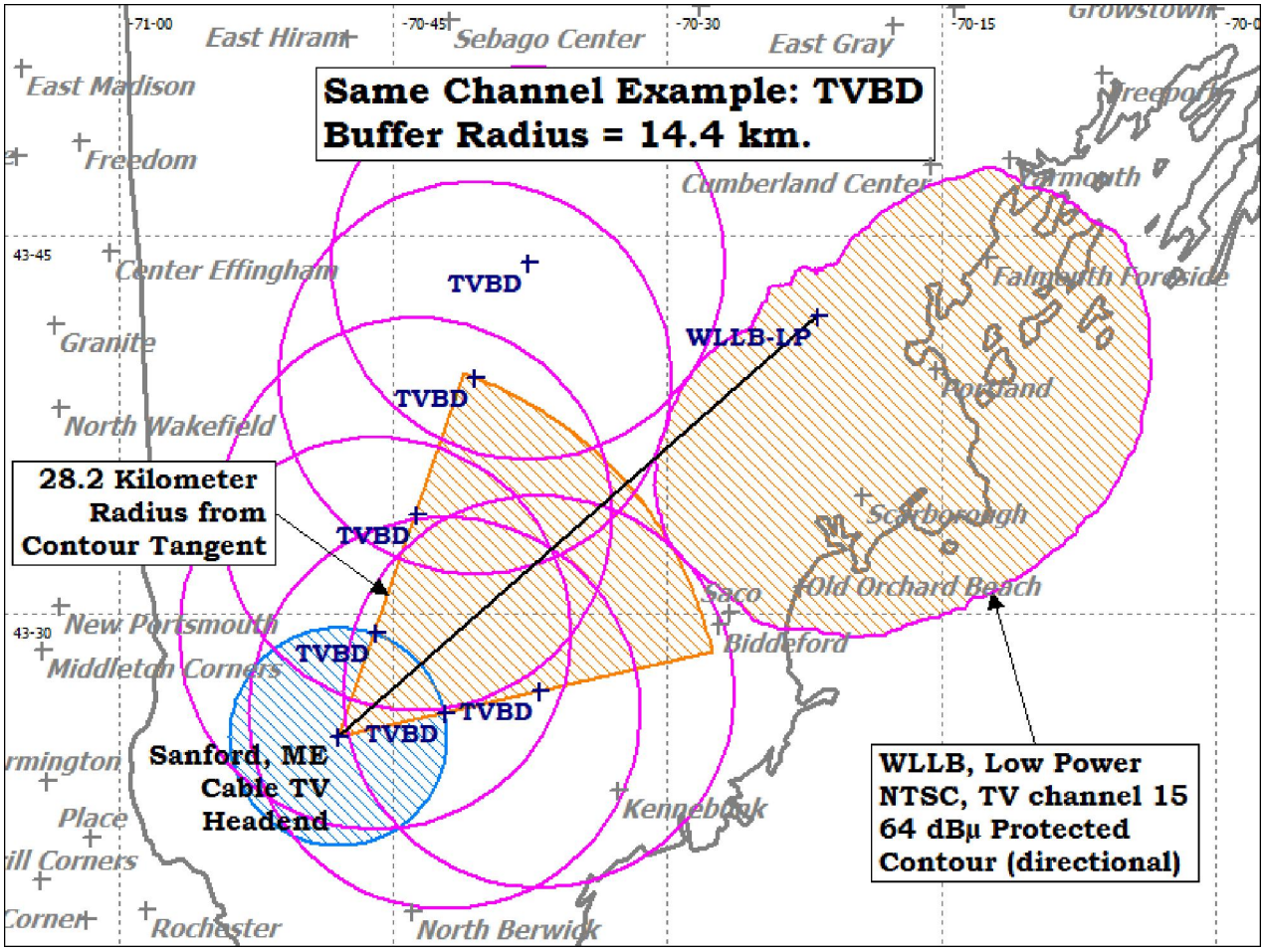


Figure 4: MVPD Receive Antenna Protection, Co-Channel

This example was drawn using real records near the actual Sanford, Maine CATV receive antenna location, but it is not known whether WLLP, Portland is actually received there or protected. It was chosen to illustrate the fact that the point of tangency which defines the protected radius of 28.8 kilometers in this case may not lie on or even close to the inter-site radial, which is drawn in black. In this example it would not be possible to operate a TVBD much less than the proscribed 30°(from §15.712), though that may not always be true. If the test was to operate the TVDB on either TV channel 14 or 16 (adjacent), devices could be operated even on the inter-site radial, as shown in Figure 5.

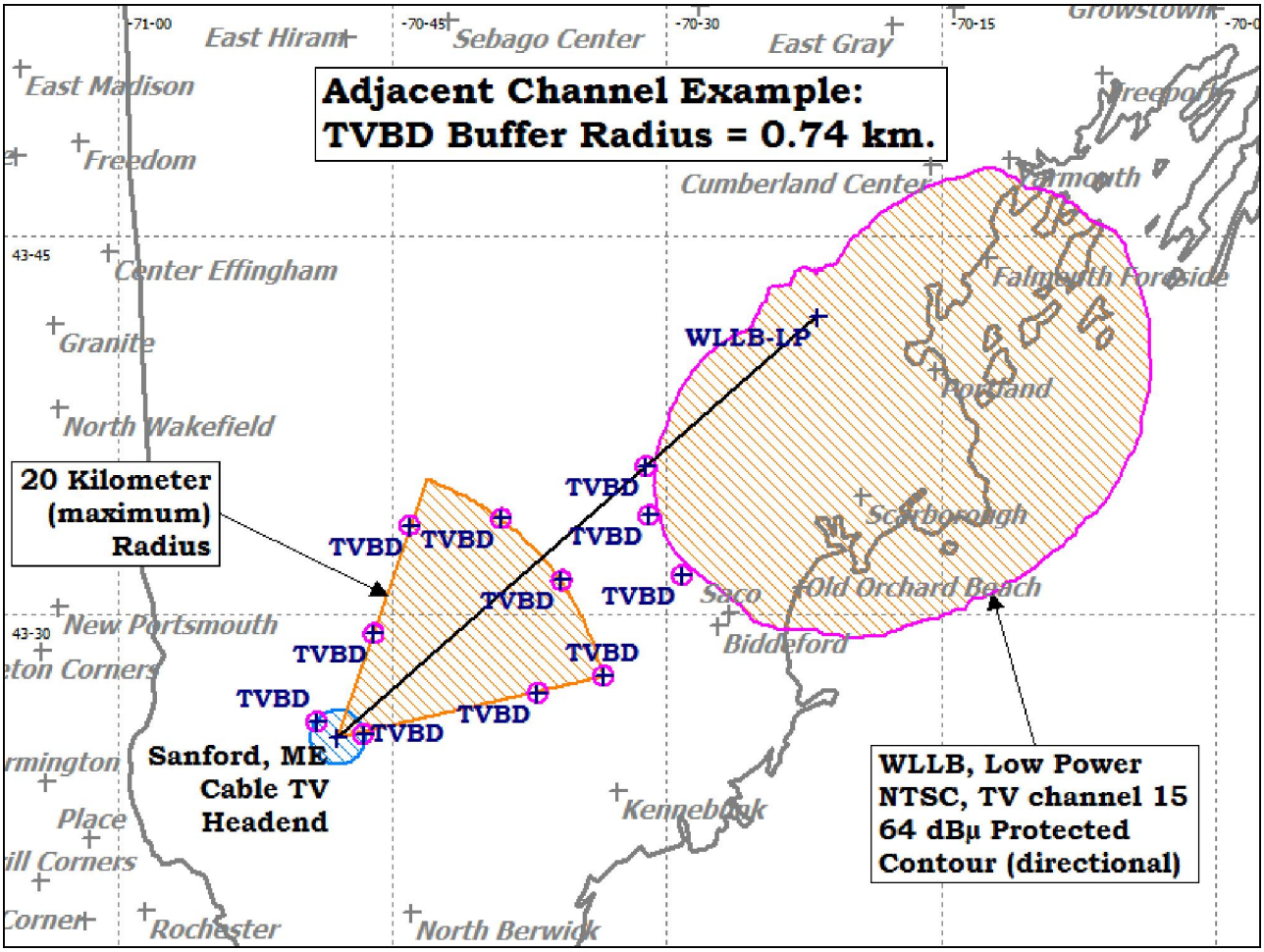


Figure 5: MVPD Receive Antenna Protection, Adjacent Channel

6.4 Radio Astronomy Sites

The following are the locations of the Radio Astronomy sites to be protected on all channels, as updated by NTIA:

Telescope	Name	City	State	LatDMS	LonDMS
Allen Telescope Array	Allen Telescope Array	Hat Creek	CA	40-49-4	-121-28-24
National Astronomy and Ionosphere Center (NAIC), Arecibo Observatory	Arecibo Observatory	Arecibo	PR	18-20-37	-66-45-11
National Radio Astronomy Observatory (NRAO), Robert C. Byrd Green Bank Telescope	Green Bank Telescope	Green Bank	WV	38-25-59	-79-50-23
National Radio Astronomy Observatory (NRAO), Very Long Baseline Array Station	VLBA - Brewster, WA	Brewster	WA	48-7-52	-119-41-00
National Radio Astronomy Observatory (NRAO), Very Long Baseline Array Station	VLBA - Fort Davis, TX	Fort Davis	TX	30-38-6	-103-56-41
National Radio Astronomy Observatory (NRAO), Very Long Baseline Array Station	VLBA - Hancock, NH	Hancock	NH	42-56-1	-71-59-12
National Radio Astronomy Observatory (NRAO), Very Long Baseline Array Station	VLBA - Kitt Peak, AZ	Kitt Peak	AZ	31-57-23	-111-36-45
National Radio Astronomy Observatory (NRAO), Very Long Baseline Array Station	VLBA - Los Alamos, NM	Los Alamos	NM	35-46-30	-106-14-44
National Radio Astronomy Observatory (NRAO), Very Long Baseline Array Station	VLBA - Mauna Kea, HI	Mauna Kea	HI	19-48-5	-155-27-20
National Radio Astronomy Observatory (NRAO), Very Long Baseline Array Station	VLBA - North Liberty, IA	North Liberty	IA	41-46-17	-91-34-27
National Radio Astronomy Observatory (NRAO), Very Long Baseline Array Station	VLBA - Owens Valley, CA	Owens Valley	CA	37-13-54	-118-16-37
National Radio Astronomy Observatory (NRAO), Very Long Baseline Array Station	VLBA - Pie Town, NM	Pie Town	NM	34-18-4	-108-7-9
National Radio Astronomy Observatory (NRAO), Very Long Baseline Array Station	VLBA - Saint Croix, VI	Saint Croix	VI	17-45-24	-64-35-1
Naval Radio Research Observatory (NRRO), Navy Information Operations Command (NIOC)	Sugar Grove Research Station	Sugar Grove	WV	38-30-58	-79-16-48
Table Mountain Radio Receiving Zone of the Research Laboratories of the Department of Commerce	Table Mountain	Boulder	CO	40-8-2	-105-14-40
National Radio Astronomy Observatory (NRAO), Very Large Array	Very Large Array	Socorro	NM	Rectangle (no 2.4 km radius) between latitudes 33 58 22 N and 34 14 56 N, and longitudes 107 24 40 W and	

Telescope	Name	City	State	LatDMS	LonDMS
				107 48 22 W	

7. F-Curve Interpolation Data Points

7.1 D10 Values

items 1-7	16.093440	32.186880	48.280320	64.373760	80.467200	96.560640	112.654080
items 8-14	128.747520	144.840960	160.934400	177.027840	193.121280	209.214720	225.308160
items15-21	241.401600	257.495040	273.588480	289.681920	305.775360	321.868800	337.962240
items 22-28	354.055680	370.149120	386.242560	402.336000	418.429440	434.522880	450.616320
items 29-31	466.709760	482.803200	498.896440				

7.2 D50 Values

items 1-7	1.609344	3.218688	4.828032	6.437376	8.046720	16.093440	32.186880
items 8-14	48.280320	64.373760	80.467200	96.560640	112.654080	128.747520	144.840960
items15-21	160.934400	177.027840	193.121280	209.214720	225.308160	241.401600	257.495040
items 22-25	273.588480	289.681920	305.775360	321.868800			

7.3 H10 Values

items 1-7	30.48	60.96	121.92	182.88	243.84	304.80	381.00
items 8-13	457.20	533.40	609.60	914.40	1,219.20	1,524.00	

7.4 H50 Values

items 1-7	30.48	60.96	121.92	182.88	243.84	304.80	381.00
items 8-13	457.20	533.40	609.60	914.40	1,219.20	1,524.00	

7.5 F51LV Values

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1	52.2	58.4	64.3	68.0	70.5	72.3	74.2	75.9	77.0	78.2	80.8	81.8	82.2
2	41.4	47.0	53.0	56.5	59.0	60.9	63.0	64.8	66.2	67.6	71.2	73.8	75.5
3	36.4	40.9	45.9	49.0	51.7	53.7	56.0	57.9	59.6	60.9	64.5	67.0	69.0
4	33.0	36.0	39.9	43.0	45.4	47.5	50.0	52.0	54.0	55.2	58.9	61.4	63.3
5	30.0	31.9	35.0	37.7	40.0	41.9	44.4	46.7	48.5	50.0	53.9	56.3	58.4
6	26.7	28.0	30.5	32.8	34.9	36.8	39.2	41.6	43.5	45.0	49.0	51.7	53.5
7	23.5	24.9	26.9	28.8	30.4	32.0	34.9	37.1	39.2	40.7	44.2	46.9	48.8
8	20.4	22.0	24.0	25.6	27.0	28.4	30.8	33.0	35.0	36.2	39.8	42.0	44.0
9	17.4	19.0	20.9	22.5	23.9	25.0	27.0	29.0	30.8	32.0	35.4	37.8	39.7
10	14.5	16.1	18.2	19.8	21.0	22.0	23.9	25.5	26.9	28.0	31.3	33.8	35.7

11	11.5	13.1	15.3	16.9	18.2	19.2	20.8	22.0	23.2	24.1	27.6	30.0	32.1
12	8.5	10.1	12.4	13.9	15.1	16.2	17.8	19.0	20.0	21.0	24.4	27.0	29.1
13	5.9	7.7	9.8	11.0	12.3	13.4	14.8	16.0	17.1	18.0	21.6	24.1	26.1
14	3.0	4.9	6.9	8.2	9.7	10.7	12.0	13.2	14.2	15.3	18.9	21.5	23.5
15	0.6	2.0	4.1	5.7	6.9	8.0	9.1	10.3	11.6	12.5	16.0	18.8	20.9
16	-2.0	-0.4	1.6	2.9	4.1	5.3	6.7	7.9	9.0	10.0	13.6	16.1	18.0
17	-4.3	-3.0	-1.0	0.3	1.6	2.7	3.9	5.0	6.0	7.0	10.7	13.6	15.7
18	-6.6	-5.1	-3.4	-2.2	-1.0	0.0	1.1	2.2	3.3	4.4	8.0	10.9	13.0
19	-8.7	-7.4	-5.8	-4.6	-3.4	-2.5	-1.4	-0.2	0.9	1.8	5.2	8.1	10.2
20	-10.5	-9.4	-8.0	-6.9	-5.7	-4.9	-3.9	-2.8	-1.8	-0.8	2.8	5.3	7.5
21	-12.5	-11.4	-10.1	-9.0	-8.0	-7.0	-6.0	-5.0	-4.0	-3.0	0.3	3.0	5.0
22	-14.6	-13.4	-12.0	-11.0	-10.0	-9.0	-8.0	-7.0	-6.2	-5.3	-2.0	0.4	2.6
23	-16.6	-15.5	-14.1	-13.0	-12.0	-11.2	-10.2	-9.2	-8.2	-7.4	-4.5	-1.9	0.0
24	-18.6	-17.4	-16.0	-15.0	-14.0	-13.2	-12.2	-11.3	-10.5	-9.8	-7.0	-4.3	-2.4
25	-20.5	-19.3	-18.0	-17.0	-16.0	-15.1	-14.2	-13.3	-12.5	-11.8	-9.0	-6.7	-4.6
26	-22.4	-21.2	-19.9	-18.9	-17.9	-17.0	-16.2	-15.3	-14.6	-14.0	-11.1	-9.0	-6.9
27	-24.3	-23.2	-21.9	-20.9	-19.9	-19.0	-18.1	-17.2	-16.3	-15.8	-13.2	-11.0	-9.0
28	-26.2	-25.0	-23.7	-22.5	-21.7	-21.0	-20.0	-19.2	-18.4	-17.8	-15.0	-12.9	-11.0
29	-28.1	-27.0	-25.6	-24.6	-23.6	-23.0	-22.0	-21.1	-20.2	-19.6	-17.0	-14.9	-13.0
30	-30.0	-29.0	-27.4	-26.3	-25.4	-24.6	-23.7	-22.8	-22.0	-21.3	-19.0	-16.9	-15.0
31	-31.9	-31.0	-29.2	-28.0	-27.2	-26.2	-25.4	-24.5	-23.8	-23.0	-21.0	-18.9	-17.0

7.6 F55LV Values

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1	92.0	98.0	100.6	101.5	101.9	102.0	102.1	102.2	102.3	102.4	102.5	102.5	102.5
2	79.7	85.9	91.0	93.4	94.6	95.0	95.6	95.9	96.0	96.1	96.3	96.5	96.5
3	72.7	79.0	84.8	87.8	89.4	90.4	91.2	91.8	92.0	92.2	92.5	92.5	92.5
4	67.8	73.8	80.0	83.3	85.4	86.8	87.7	88.3	88.9	89.2	89.9	90.1	90.2
5	64.0	70.0	76.0	79.6	82.0	83.7	85.0	85.8	86.3	86.7	87.6	88.0	88.1
6	52.0	58.0	64.0	67.6	70.0	72.0	73.9	75.4	76.7	77.9	80.2	81.3	81.9
7	39.4	45.5	51.5	55.0	57.6	59.6	61.7	63.3	64.9	66.2	70.0	72.4	74.2
8	31.0	37.0	43.0	46.7	49.0	51.0	53.2	55.1	57.0	58.5	62.6	65.0	66.5
9	25.3	29.5	35.5	39.0	41.5	43.6	45.9	47.9	50.0	51.5	55.4	57.8	59.6
10	20.3	23.5	28.8	32.0	34.4	36.7	39.1	41.5	43.5	45.0	48.9	51.2	53.0
11	16.2	18.1	22.0	25.3	27.7	29.9	32.0	34.4	36.7	38.2	42.5	44.9	46.4
12	12.8	14.5	17.1	19.8	22.0	23.9	26.0	28.3	30.7	32.4	36.9	39.1	40.8
13	9.8	11.0	13.4	15.2	17.0	18.8	21.0	23.2	25.2	27.0	31.0	33.2	35.0
14	6.9	8.2	10.2	11.8	13.1	14.7	16.8	18.8	20.4	22.0	25.7	28.1	30.0
15	4.0	5.5	7.4	8.9	10.1	11.5	13.1	14.9	16.0	17.3	21.0	23.5	25.5
16	1.5	2.9	4.8	6.0	7.2	8.4	9.9	11.1	12.5	13.7	17.1	19.8	21.8

17	-1.1	0.3	2.2	3.7	4.8	5.7	7.0	8.0	9.1	10.1	13.6	16.1	18.3
18	-3.6	-2.2	-0.3	1.0	2.0	3.0	4.1	5.2	6.2	7.1	10.3	13.0	15.0
19	-5.8	-4.8	-3.0	-1.4	-0.3	0.6	1.7	2.7	3.8	4.6	7.8	10.4	12.4
20	-8.1	-7.0	-5.2	-3.9	-2.7	-1.8	-0.7	0.2	1.1	2.0	5.1	8.0	10.0
21	-10.6	-9.4	-7.6	-6.1	-5.1	-4.2	-3.2	-2.2	-1.3	-0.4	2.8	5.5	7.7
22	-13.0	-11.7	-10.0	-8.7	-7.6	-6.6	-5.6	-4.6	-3.6	-2.7	0.5	3.1	5.1
23	-15.1	-14.0	-12.2	-11.0	-10.0	-9.0	-8.0	-7.0	-6.1	-5.1	-2.1	0.6	2.8
24	-17.2	-16.1	-14.6	-13.2	-12.1	-11.2	-10.2	-9.2	-8.4	-7.6	-4.5	-2.0	0.2
25	-19.2	-18.3	-16.9	-15.6	-14.6	-13.6	-12.5	-11.6	-10.6	-10.0	-6.8	-4.1	-2.0

7.7 F51HV Values

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1	55.4	61.6	67.7	71.0	73.5	75.3	77.1	78.6	79.6	80.4	82.0	82.4	82.5
2	44.4	50.0	55.8	59.1	61.7	63.7	66.5	68.9	70.8	72.0	75.0	75.9	76.2
3	39.2	43.5	48.6	52.0	54.6	56.5	59.0	61.5	63.6	65.2	68.6	69.8	70.2
4	34.0	38.0	42.7	45.6	48.0	50.0	52.5	54.9	56.9	58.8	62.5	64.0	64.9
5	29.9	32.5	35.9	38.8	41.0	43.0	45.8	48.2	50.8	53.0	57.0	58.9	59.8
6	26.6	28.2	31.0	33.4	35.4	37.4	40.0	43.0	45.4	47.6	52.0	53.8	54.8
7	23.5	25.0	27.0	28.9	30.7	32.3	35.0	37.4	40.0	42.0	46.8	48.9	50.0
8	20.3	22.0	24.0	25.5	27.0	28.3	30.4	32.9	35.0	36.8	41.5	43.7	45.0
9	17.4	19.0	21.0	22.4	23.8	25.0	26.9	28.8	30.4	32.0	35.8	38.2	40.1
10	14.3	16.0	18.1	19.6	20.8	22.0	23.5	25.0	26.4	27.7	31.0	33.6	35.5
11	11.3	13.0	15.1	16.7	18.0	19.1	20.5	22.0	23.0	24.0	27.6	30.0	32.0
12	8.6	10.0	12.2	13.7	15.0	16.3	17.6	18.8	19.9	20.7	24.0	26.8	28.9
13	5.8	7.2	9.4	10.8	12.0	13.3	14.7	15.9	17.0	18.0	21.4	24.0	26.0
14	2.9	4.7	6.8	8.1	9.5	10.6	12.0	13.0	14.1	15.2	18.8	21.2	23.4
15	0.3	1.9	3.8	5.2	6.5	7.8	9.0	10.3	11.5	12.5	16.0	18.7	20.7
16	-2.1	-0.7	1.2	2.7	3.9	5.0	6.4	7.5	8.8	9.8	13.1	15.9	18.0
17	-4.4	-3.2	-1.4	0.0	1.2	2.4	3.7	4.9	6.0	7.0	10.6	13.2	15.4
18	-6.7	-5.4	-3.8	-2.3	-1.2	0.0	1.0	2.1	3.3	4.3	7.9	10.6	12.8
19	-8.9	-7.8	-6.1	-4.8	-3.8	-2.6	-1.4	-0.3	0.8	1.7	5.0	8.0	10.0
20	-10.8	-9.8	-8.2	-7.0	-6.0	-5.0	-4.0	-3.0	-2.0	-1.0	2.5	5.2	7.3
21	-12.9	-11.8	-10.3	-9.0	-8.2	-7.1	-6.0	-5.1	-4.2	-3.3	0.0	2.8	4.9
22	-14.8	-13.8	-12.3	-11.1	-10.2	-9.3	-8.2	-7.4	-6.5	-5.6	-2.4	0.2	2.2
23	-16.9	-15.8	-14.3	-13.1	-12.2	-11.2	-10.2	-9.4	-8.6	-7.8	-4.7	-2.0	-0.1
24	-18.8	-17.7	-16.3	-15.1	-14.2	-13.3	-12.3	-11.4	-10.6	-9.8	-6.9	-4.3	-2.4
25	-20.7	-19.7	-18.3	-17.0	-16.2	-15.3	-14.3	-13.5	-12.8	-12.0	-9.0	-6.5	-4.7
26	-22.7	-21.4	-20.1	-19.0	-18.0	-17.2	-16.2	-15.4	-14.8	-14.0	-11.1	-9.0	-7.0
27	-24.6	-23.3	-22.0	-20.9	-20.0	-19.1	-18.2	-17.4	-16.8	-16.0	-13.1	-11.0	-9.0
28	-26.4	-25.2	-24.0	-22.9	-21.9	-21.0	-20.0	-19.2	-18.5	-18.0	-15.1	-13.0	-11.0

29	-28.2	-27.1	-25.9	-24.8	-23.9	-23.0	-22.0	-21.1	-20.3	-19.6	-17.0	-15.0	-13.0
30	-30.1	-29.0	-27.7	-26.5	-25.5	-24.9	-23.9	-23.0	-22.1	-21.5	-19.0	-16.8	-15.0
31	-32.0	-30.9	-29.5	-28.2	-27.1	-26.7	-25.8	-24.9	-23.9	-23.4	-21.0	-18.6	-17.0

7.8 F55HV Values

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1	94.6	100.7	101.6	101.8	101.9	102.0	102.3	102.3	102.3	102.4	102.4	102.4	102.5
2	82.8	88.9	92.3	93.9	94.6	95.0	95.4	95.7	95.9	96.0	96.2	96.2	96.5
3	75.7	81.8	86.6	88.7	89.8	90.5	91.3	91.8	92.0	92.1	92.6	92.6	92.7
4	70.7	76.9	82.2	84.8	86.2	87.0	88.0	88.7	89.1	89.5	90.0	90.0	90.1
5	66.8	73.0	78.8	81.6	83.2	84.5	85.7	86.3	87.0	87.3	88.0	88.0	88.0
6	55.0	61.0	67.2	70.8	73.2	75.0	77.0	78.1	79.1	80.0	81.1	81.8	82.0
7	42.5	48.6	54.7	58.1	60.7	62.5	65.0	67.6	69.5	71.0	73.9	74.8	75.0
8	34.0	40.0	46.1	49.8	52.1	54.2	56.7	59.0	61.0	62.8	66.3	67.4	68.0
9	26.3	32.0	38.1	41.7	44.0	46.0	48.8	51.0	53.3	55.0	58.7	60.3	61.1
10	20.7	24.1	30.1	33.8	36.1	38.0	40.9	43.5	46.0	47.9	52.0	53.8	54.6
11	16.3	18.5	23.0	26.2	28.8	30.6	33.5	36.3	39.0	41.0	45.0	47.0	48.1
12	12.9	14.4	17.0	20.0	22.1	24.0	26.8	29.6	32.0	34.0	38.2	40.6	42.0
13	9.9	11.2	13.5	15.2	17.0	18.9	21.2	23.9	26.0	28.0	32.0	34.4	36.1
14	7.0	8.3	10.5	12.0	13.7	15.0	17.0	19.0	21.0	22.6	26.3	28.8	30.6
15	4.3	5.5	7.5	9.0	10.4	11.5	13.1	14.9	16.2	17.5	21.1	23.8	25.5
16	1.5	2.9	4.8	6.2	7.5	8.6	10.0	11.2	12.7	13.6	17.0	19.8	21.8
17	-1.0	0.5	2.3	3.7	4.8	5.8	7.0	8.2	9.5	10.5	14.0	16.6	18.5
18	-3.5	-2.0	-0.3	1.0	2.2	3.2	4.4	5.5	6.5	7.4	10.7	13.1	15.1
19	-5.7	-4.3	-2.7	-1.2	-0.1	0.9	2.0	3.0	4.0	4.9	8.0	10.4	12.3
20	-8.0	-6.9	-5.0	-3.7	-2.5	-1.5	-0.5	0.6	1.5	2.2	5.6	8.2	10.1
21	-10.4	-9.2	-7.3	-6.0	-4.9	-4.0	-3.0	-2.0	-1.0	-0.2	3.0	5.5	7.5
22	-12.8	-11.5	-9.8	-8.4	-7.3	-6.3	-5.3	-4.3	-3.5	-2.6	0.6	3.1	5.1
23	-15.0	-13.8	-12.0	-10.7	-9.7	-8.7	-7.6	-6.6	-5.8	-5.0	-1.8	0.9	2.9
24	-17.2	-16.0	-14.4	-13.0	-12.0	-11.0	-10.0	-9.0	-8.2	-7.3	-4.2	-1.8	0.3
25	-19.1	-18.2	-16.8	-15.5	-14.4	-13.4	-12.3	-11.3	-10.5	-9.8	-6.6	-4.0	-1.9

7.9 F51U Values

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1	52.2	58.3	64.7	68.0	70.5	72.3	74.1	75.4	76.4	77.4	79.5	80.7	81.3
2	41.6	46.7	52.4	56.0	58.5	60.3	62.3	63.9	65.2	66.2	69.3	71.2	72.6
3	35.0	38.0	43.0	46.3	48.8	50.8	52.9	54.9	56.3	57.6	60.9	63.0	64.5
4	30.3	32.1	35.3	37.6	40.0	42.4	45.1	47.1	48.7	50.0	53.6	56.1	58.0
5	27.0	28.3	30.8	32.6	34.7	36.7	39.0	40.8	42.4	43.7	47.7	50.2	52.4
6	23.8	25.2	27.6	29.1	30.4	32.0	34.5	36.4	37.9	39.0	43.1	46.0	48.0

7	20.8	22.2	24.5	26.0	27.2	28.4	30.4	32.2	33.9	35.1	39.2	42.1	44.3
8	17.8	19.3	21.3	23.0	24.2	25.4	27.0	28.8	30.2	31.7	35.8	38.7	40.7
9	14.8	16.5	18.5	20.0	21.2	22.4	23.9	25.2	26.6	27.8	32.0	35.0	37.3
10	12.0	13.4	15.6	17.1	18.3	19.7	21.0	22.1	23.4	24.6	28.3	31.3	33.8
11	9.2	10.7	12.7	14.0	15.2	16.5	18.0	19.3	20.3	21.3	24.9	27.8	30.3
12	6.6	8.0	9.9	11.2	12.6	13.8	15.3	16.4	17.3	18.3	21.7	24.3	27.0
13	4.0	5.1	7.1	8.8	10.0	11.0	12.5	13.8	14.8	15.7	18.8	21.2	23.7
14	1.2	2.5	4.4	6.0	7.3	8.3	9.7	10.9	11.9	12.8	15.9	18.2	20.5
15	-1.3	-0.2	1.8	3.2	4.6	5.7	7.0	8.1	9.1	10.0	13.1	15.5	17.4
16	-3.8	-2.4	-0.8	0.8	1.9	3.0	4.4	5.6	6.7	7.6	10.6	12.8	14.7
17	-6.0	-4.9	-3.1	-1.7	-0.5	0.6	1.8	2.9	3.9	4.8	7.9	10.0	12.0
18	-8.4	-7.2	-5.5	-4.1	-3.0	-2.0	-0.7	0.3	1.3	2.1	5.1	7.3	9.2
19	-10.3	-9.3	-7.7	-6.2	-5.2	-4.3	-3.2	-2.2	-1.2	-0.4	2.2	4.7	6.5
20	-12.5	-11.3	-9.8	-8.4	-7.4	-6.6	-5.4	-4.5	-3.6	-2.8	0.0	2.1	4.0
21	-14.5	-13.5	-12.0	-10.4	-9.6	-8.8	-7.7	-6.7	-5.8	-5.0	-2.2	0.0	1.8
22	-16.5	-15.5	-14.0	-12.7	-11.7	-10.8	-9.8	-8.9	-7.9	-7.1	-4.3	-2.2	-0.4
23	-18.5	-17.4	-15.9	-14.6	-13.8	-13.0	-12.0	-11.0	-10.0	-9.2	-6.6	-4.6	-2.8
24	-20.5	-19.3	-17.8	-16.5	-15.6	-14.9	-14.0	-13.0	-12.2	-11.3	-8.9	-6.8	-5.0
25	-22.4	-21.3	-19.8	-18.6	-17.7	-17.0	-16.0	-15.0	-14.2	-13.4	-11.0	-8.8	-7.0
26	-24.2	-23.2	-21.6	-20.4	-19.6	-18.9	-17.9	-17.0	-16.2	-15.4	-13.0	-10.8	-9.0
27	-26.0	-25.0	-23.4	-22.2	-21.3	-20.8	-19.9	-19.1	-18.2	-17.5	-15.0	-12.9	-11.0
28	-27.8	-27.0	-25.5	-24.2	-23.3	-22.7	-21.8	-21.0	-20.2	-19.4	-17.0	-14.9	-13.0
29	-29.5	-28.5	-27.1	-26.0	-25.0	-24.4	-23.7	-22.8	-22.0	-21.3	-19.0	-16.9	-15.0
30	-31.0	-30.1	-28.9	-27.9	-27.0	-26.3	-25.6	-24.8	-24.0	-23.2	-21.0	-18.9	-16.8
31	-32.5	-31.6	-30.7	-29.8	-29.0	-28.2	-27.5	-26.8	-26.0	-25.1	-22.9	-20.9	-18.6

7.10 F55U Values

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1	92.0	97.9	100.7	101.5	101.9	102.0	102.1	102.2	102.3	102.4	102.5	102.5	102.5
2	80.0	86.0	91.0	93.0	94.1	94.8	95.2	95.6	95.9	96.0	96.3	96.5	96.5
3	72.9	79.0	84.7	87.4	89.0	90.0	90.8	91.3	91.8	92.0	92.5	92.8	93.0
4	67.9	74.0	80.0	83.3	85.1	86.3	87.3	88.0	88.6	88.9	89.6	90.0	90.3
5	63.8	70.0	76.0	79.5	81.5	82.9	84.1	85.0	85.8	86.2	87.3	87.9	88.1
6	51.9	58.0	64.0	67.6	70.0	72.0	73.8	75.3	76.5	77.2	79.6	80.5	81.0
7	39.0	45.2	51.2	54.6	57.2	59.1	61.0	62.6	64.0	65.0	68.2	70.0	71.1
8	27.5	33.5	39.6	43.0	45.7	48.0	50.5	52.3	53.9	55.0	58.4	60.8	62.5
9	17.8	22.7	28.2	31.5	34.5	37.3	40.3	42.7	44.3	45.7	49.4	52.1	54.0
10	13.0	16.0	19.6	22.3	25.1	28.3	31.8	34.1	36.0	37.6	41.7	44.8	46.7
11	10.1	11.7	14.4	16.8	19.1	21.7	24.7	27.0	29.3	31.0	35.4	38.6	41.0
12	7.0	8.5	10.8	12.5	14.2	16.3	19.0	21.3	23.4	25.0	29.8	33.0	35.7

13	4.2	5.5	7.7	9.3	10.8	12.4	14.5	16.3	18.0	19.8	24.5	28.0	30.8
14	1.6	2.8	4.7	6.0	7.5	8.9	10.6	12.0	13.6	15.0	19.8	23.4	26.0
15	-1.0	0.2	1.9	3.2	4.6	5.7	7.1	8.5	9.7	10.8	15.0	18.8	21.8
16	-3.2	-2.0	-0.4	0.7	1.9	3.0	4.3	5.6	6.7	7.7	11.5	14.8	17.5
17	-5.0	-4.2	-2.7	-1.5	-0.4	0.5	1.7	2.8	3.8	4.8	8.2	11.1	13.7
18	-7.2	-6.3	-4.9	-3.8	-2.9	-2.0	-0.9	0.0	1.0	1.9	5.0	7.8	10.0
19	-9.1	-8.4	-7.0	-5.9	-5.0	-4.2	-3.2	-2.3	-1.6	-0.9	2.0	4.6	6.7
20	-11.0	-10.3	-8.9	-7.9	-7.0	-6.1	-5.2	-4.3	-3.6	-3.0	-0.2	1.9	3.7
21	-13.1	-12.3	-10.9	-9.9	-9.0	-8.0	-7.1	-6.2	-5.5	-4.8	-2.2	-0.1	1.7
22	-15.1	-14.2	-12.8	-11.7	-10.8	-10.0	-9.0	-8.2	-7.5	-6.8	-4.3	-2.2	-0.4
23	-17.2	-16.2	-14.8	-13.8	-12.8	-11.9	-11.0	-10.2	-9.5	-8.9	-6.3	-4.2	-2.3
24	-19.3	-18.3	-16.8	-15.8	-14.8	-13.9	-13.0	-12.2	-11.4	-10.8	-8.3	-6.1	-4.4
25	-21.4	-20.1	-18.7	-17.7	-16.8	-15.9	-15.0	-14.1	-13.2	-12.5	-10.0	-8.0	-6.3